This lesson fits into the following Science Standards.

Science as Inquiry (from http://www.nap.edu/readingroom/books/nses/html/index.html)
From the National Standards

- Content Standards A and D

Lesson Plan

Objectives

1. Students will be able to identify questions and concepts that guide scientific investigations.
2. SWBAT use technology and mathematics to improve investigations and communications.
3. SWBAT formulate and revise scientific explanations and models using logic and evidence.

Grade Level

High School (Earth Science or Physics)

Author

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Prerequisites

Students will need the following skills:

1. ability to graph data and analyze the data
2. an introductory knowledge of astronomy and how to detect objects in space
3. working knowledge of the electromagnetic spectrum

Time

The teacher has some control over how long this takes. The teacher sets time limits at each station. Also, if more than one computer is available for use at any given time, parts of this may be given for homework. It will take about 110 minutes as written.

Materials

All of the following will be needed.

1. Graph paper
2. Ruler
3. Computer (at least one)
4. Printed version of articles if the students will not have access to a computer to view them
5. AstroCapella 2.0 CD and CD player
6. Candle and matches
7. Three pieces of adjoined computer paper (or three pieces of paper taped together lengthwise with a line drawn through the middle (for use in activity IV)
8. Cards with parts of the EM spectrum written on them (see activity IV)

Warm Up

1. Have students listen to the High Energy Groove song from AstroCapella
2. Have students listen and read the words this time just to the second verse, while they are listening the students will write down any words that they hear that relate to astronomy or a topic that they have heard and define them from previous knowledge
3. Either go around the room for responses or collect responses or have students in group discuss the definitions (teacher depending)
4. Make a list of the science words they discussed in class

Body

Split the class into five groups. The groups will have about 20 minutes to complete each of the following activities. Each activity is designed for groups and each has an assessment built into it. It is the teacher's responsibility to set up and monitor the activities. The groups will rotate through all of the activities.

I. Articles with questions
II. Wein's Law (need candle and holder with matches)
III. Graphing and analyzing the graphs
IV. EM Spectrum
V. Web quest on computer

Activities

I. Articles

Each group will be assigned one of the following articles. The sites for articles related to the song are below. Each group will be given the questions associated with their article, because they are appropriate to their specific article. The article can be found online or printed by the teacher before class (if there is a limited amount of time or computer space). See the worksheets for the questions on each article.

Web Sites for the articles are below and the worksheets are on the next five pages.

1. http://chandra.harvard.edu/press/01_releases/press_020101.html

2. http://chandra.harvard.edu/press/02_releases/press_062502.html

3. http://chandra.harvard.edu/press/02_releases/press_020602.html

4. http://universe.gsfc.nasa.gov/press/2002/020422d.html

5. http://chandra.harvard.edu/press/02_releases/press_041902.html

Name _____
Date _____
Period _____

Activity I
Article One

You are to read the article either from the paper version or the computer version. If you have the computer version, please make sure to access the links and look at the pictures to gain a full understanding of the image and text in front of you.

Name of article assigned to you _____

Web site of article http://chandra.harvard.edu/press/01_releases/press_020101.html

Answer the questions based on the article. Write your answers on your own paper. Make sure that you use COMPLETE sentences and complete thoughts when answering the questions.

1. What did scientists find in the center of our galaxy? What body may it help to regulate?

2. Where is Srg A East located (specifically), and how old is it?

3. What kinds of elements are found in Srg A East? Why is their presence in the object important?

4. What effects did the two shock waves each have after the supernova explosion?

5. What conclusions did radio astronomers make in regards to the halo of gas surrounding Sgr A East?

6. Based on this result, develop a theory about what powers distant active galaxies posess.

Name _____
Date _____
Period _____

Activity I
Article Two

You are to read the article either from the paper version or the computer version. If you have the computer version, please make sure to access the links and look at the pictures to gain a full understanding of the image and text in front of you.

Name of article assigned to you _____

Web site of article http://chandra.harvard.edu/press/02_releases/press_062502.html

Author(s) of the article _____

Answer the questions based on the article. Write your answers on your own paper. Make sure that you use COMPLETE sentences and complete thoughts when answering the questions.

1. Where did scientists find the "Bulls-eye" pulsar? How are scientists going to use this discovery by the Chandra X-ray observatory?

2. What, specifically, did the image of the supernova show?

3. How old is the pulsar? How large is the ring surrounding the pulsar?

4. How are high-energy particles, which can be seen in the X-ray spectrum, formed?

5. Where and how was the neutron star formed?

Name _____
Date _____
Period _____

Activity I
Article Three

You are to read the article either from the paper version or the computer version. If you have the computer version, please make sure to access the links and look at the pictures to gain a full understanding of the image and text in front of you.

Name of article assigned to you _____

Web site of article http://chandra.harvard.edu/press/02_releases/press_020602.html

Answer the questions based on the article. Write your answers on your own paper. Make sure that you use COMPLETE sentences and complete thoughts when answering the questions.

1. What does this picture reveal to NASA scientists about the distant galaxy and the quasar PKS 1127-145?

2. How will scientists use the information gathered from the quasar PKS 1127-145 (3 ways)?

3. How did scientists get the information gathered from the quasar PKS 1127-145?

4. How can scientists measure the amount of oxygen in distant galaxies?

5. How are oxygen and silicon distributed through out the galaxies?

Name _____
Date _____
Period _____

Activity I
Article Four

You are to read the article either from the paper version or the computer version. If you have the computer version, please make sure to access the links and look at the pictures to gain a full understanding of the image and text in front of you.

Name of article assigned to you _____

Web site of article http://universe.gsfc.nasa.gov/press/cw02_13.html

Answer the questions based on the article. Write your answers on your own paper. Make sure that you use COMPLETE sentences and complete thoughts when answering the questions.

1. How did the scientists measure the neutron star's orbital velocity? What is the Doppler shift?

2. What two theories did this discovery help to confirm?

3. Why did the scientists believe that neutron stars may evolve into fast-spinning pulsars?

4. Compare and contrast the different characteristics of the neutron star and pulsar.

5. Why (two ways) is using X-ray radiation a good way to observe the neutron star?

Name _____
Date _____
Period _____

Activity I
Article Five

You are to read the article either from the paper version or the computer version. If you have the computer version, please make sure to access the links and look at the pictures to gain a full understanding of the image and text in front of you.

Name of article assigned to you _____

Web site of article http://chandra.harvard.edu/press/02_releases/press_041902.html

Answer the questions based on the article. Write your answers on your own paper. Make sure that you use COMPLETE sentences and complete thoughts when answering the questions.

1. What is the size of the galaxies from the picture? What is happening to the galaxies? Why is this picture important to scientists?

2. What happened when the smaller galaxies joined to formed Arp 220?

3. How does an event such as this affect the formation of the galaxy?

4. How close is the Arp 220 galaxy to us? How much radiation does the galaxy give off relative the amount of radiation the sun gives off?

5. Describe the two theories that explain the extraordinary luminosity of Arp 220?

II. Wein's Law

The students will need a brief knowledge of Wein's law, lab rules, and basic algebra. The following worksheet contains the student information and questions to answer. The students only need supervision and eye protection when lighting the candle.

The following web site was used as background information.

www.ldeo.columbia.edu/dees/ees/climate/lectures/energy/wavelength.html

The following pages are the student worksheets.

*****For teachers with more than one computer in the classroom*****

Another good way to teach students Wein's Law is through the Internet. Sending the students to http://csep10.phys.utk.edu/guidry/java/wien/wien.html will give them visual aides and activities dealing with Wein's Law. It is a good substitution to the activity below.

Name _____
Date _____
Period _____

Activity II
Wein's Law

1. Wein's Law describes the relationship between the wavelength of maximum intensity of a black body to its temperature.

Wein's Law
$\lambda_{max} = a/T$
a = 2989 if λ (intensity) is measured in microns (constant)
λ_{max} = maximum intensity
T = Temperature measured in Kelvin
Remember that K = 273 + C

(From the site www.ldeo.columbia.edu/dees/ees/climate/lectures/energy/wavelength.html)

2. An example:

Picture liquid iron. It starts out as a very hot liquid and gives off a very bright, white light. As the liquid iron cools its color changes to yellow then orange and finally to red. At room temperature it is gray or black. At this point the peak wavelength of emission is outside the visible spectrum, and we can no longer detect any changes with our eyes. This, however, is a good example of how the temperature is affecting the intensity and type of radiation given off by an object.

(The idea is from the web site http://www.geography4kids.com/files/en_temp.html, which is no longer available.)

Question

1. According to the above data how are the color of an object and the radiation interrelated? _____

_____

2. Give another example of the same phenomenon described in #2 above.

_____

_____

Activity ***YOU WILL NEED **EYE PROTECTION** FOR THIS PART OF THE ACTIVITY***

1. Carefully light the candle in front of you. Make sure that you strike the match away from you and that the match is completely out and cool before you through it into the trash can. Watch the candle burn.

2. Look carefully to flame. What color is the flame closest to the bottom of the wick? _____ What is the color of the flame farthest from the wick? _____

3. Sketch and COLOR the flame and wick as it appears on the candle. Make sure that you include all of the subtle color changes found on the flame in your sketch.

A) What colors do you observe within the flame?

_____

B) What do the different colors of the candle tell you about the temperatures of the flame. Describe one "real life" experience where this data is helpful.

_____

_____

_____

Calculation

1. Use Wein's law to determine the following answers.

   A) A scientist measured the temperature of a celestial body at 270 degrees Celsius. What would the maximum wavelength intensity of this body be? **Show your work.**

   B) What part of the EM spectrum does this wavelength fit into?

   _____

   _____

   C) Would you be able to detect this type of radiation on the surface of the Earth?

   Why? _____

   _____

   _____

   _____

   D) How would this information be useful if you were trying to study this celestial body? (three ways)

   _____

   _____

   _____

III. Analyze the graphs

The students will need a brief knowledge of graphing and graph interpretation. They will also need graph paper, pencils, and rulers. The following worksheet contains student information and questions to answer.

The following web site was used as background information.
http://www.amastro.org/at/ph/phwl.html

The student worksheets are on the following pages.

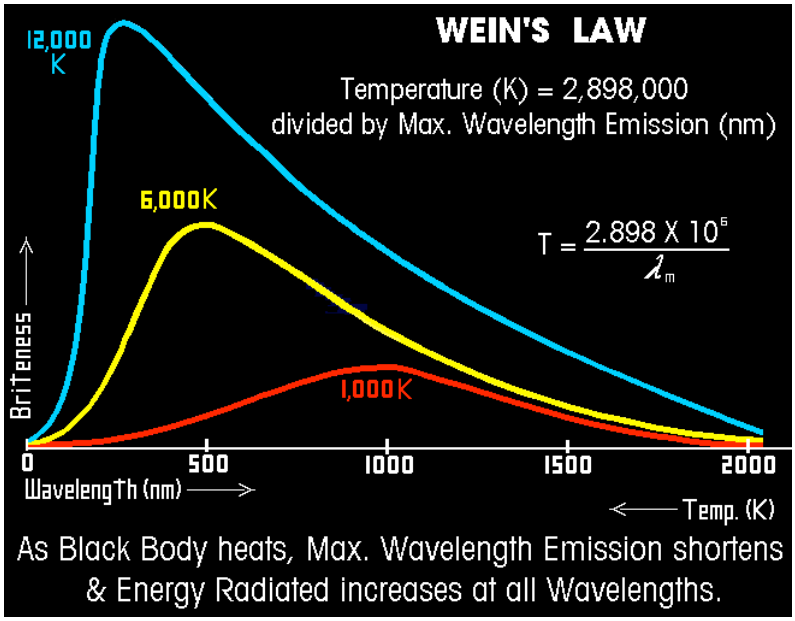
Name _____
Date _____
Period _____

Activity III
Graphing

1. There are many types of graphs that scientists use to describe the world around them. One type of graph is a spectral graph. The spectral graph looks at the electromagnetic spectrum and compares it to a specific characteristic (for example brightness). Below are two spectral graphs.

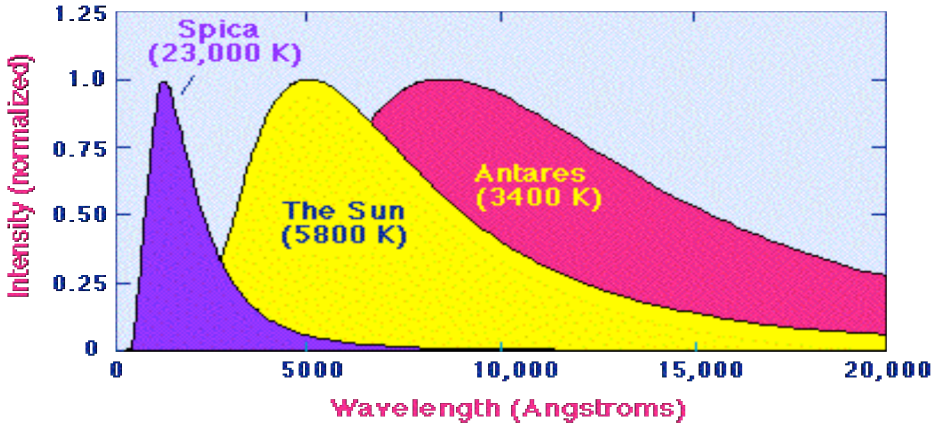
Analyze the graph

Analyze the image from (http://www.amastro.org/at/ph/phwl.html)



Below is another type of spectral graph. The following spectral graph compares the wavelength of the EM spectrum to the intensity of the wave.

Analyze this image from http://csep10.phys.utk.edu/astr162/lect/stars/cindex.html



QUESTIONS:

1. What do the graphs describe in relationship to temperature, wavelength, and brightness emission spectrums from a black body? _____

   _____

2. Compare and contrast the wavelengths between Spica, The Sun, and Antares.

   _____

   _____

   _____

3. Why is it very important for the scientists to have a working knowledge of Wein's Law in their studies of X-ray radiation?

   _____

   _____

2. A second type of graph is a light curve. In the following light curve time and the pulses of light coming from an X-ray binary star system are compared. This is different from the spectral graph in many ways. After you graph the following light curve think about the differences between the two types of graphs.

Graphing Activity

1. Graph the following real data from the Vela X-1 283 second pulsar data on your graph paper. Vela X-1 is an X-ray binary star system with a normal star orbiting along with a neutron star pulsar.

Pulses (Counts/sec)	Time (s)
550	8050
370	8060
215	8075
160	8080
170	8085
199	8110
230	8125
375	8145
380	8150
383	8155
380	8160
330	8180
440	8200
399	8210
210	8225
145	8230
140	8235
330	8250
475	8255
485	8265
425	8275
440	8290
355	8310
358	8320
360	8330
380	8340
320	8347
140	8360
145	8370
142	8375
170	8395

150	8400
210	8425
360	8440
315	8460
425	8475
330	8490
202	8510
140	8530
435	8540
480	8545
460	8550
470	8555
395	8590
450	8605
500	8625
425	8640
210	8655
240	8660
200	8665
210	8670
165	8675

QUESTIONS:

1. What are the maximum and minimum points from your graph?

   _____

2. How many cycles of data did you graph? _____

3. Why do you think there is such a fluctuation in the data?

   _____

   _____

   _____

4. What do the shape of the curve and the fluctuations tell you about the emissions coming from the Neutron Star Pulsar?

_____

_____

5. How does this graph correlate to or help to explain the nature of the object?

_____

_____

_____

6. Compare and contrast the light curve and the spectral curves.

_____

_____

_____

_____

_____

_____

IV. EM Spectrum

In order to do this activity the teacher will need to set up the following pieces of "equipment" prior to the students arrival to class.

1. Get a long poster board or tape about four pieces of regular sized paper together lengthwise. You can laminate this for safe keeping. On the paper you will need to draw a long line down the middle. This paper will be used to represent the EM spectrum.

2. You will need 3x5 cards or pieces of construction paper all cut to about the same size. You will need three colors of cards or construction paper.

3. On the green cards place one of the following words per card.

Red	UV Rays
IR waves	orange
Microwaves	yellow
Radio Waves	green
Visible light	blue
Gamma Rays	indigo
X-rays	violet

These represent the different parts of the spectrum.

4. On the yellow cards place one of the following words per card.

10^{-3} nm
1 nm
1 mm
1 m
1 km
10^{-6} nm

These numbers represent the wavelengths of the different parts of the spectrum.

5. On the pink cards place on the following words per card.

The Electromagnetic Spectrum
High frequency
Low frequency
High Wavelength
Low Wavelength

In order for the students to complete this activity they will need a working knowledge of the EM spectrum and its parts. The activity is explained in the student worksheet. It is important for the teacher to understand that the green cards will be located above the line

(from #1 above), the yellow cards will be located below the line, and the pink cards will be located above or below the line as appropriate. The teacher may wish to use Velcro to stick the cards directly onto the lined paper. Another option is for the teacher to simply draw a line on the blackboard. The cards can all have magnets on the back of them, and the students can simply stick the cards on the board as appropriate. This will prevent problems of the cards blowing off of the paper.

See the following page for the student worksheet and questions to answer.

Name _____
Date _____
Period _____

Activity IV
Electromagnetic Spectrum

Please use the cards on your table to complete the following activities and answer the following questions.

Activity

1. Arrange the cards on the line provided by your teacher.

    - The line may be drawn on poster board or the board.
    - You should notice that there are three different colors of cards on the table.
    - The yellow cards should be placed in their appropriate places below the line, the green cards should be placed in their appropriate places above the line, and the pink cards should be placed in their appropriate places above and below the line.
    - Everyone in the group is to participate in this activity.

2. Now that you have the cards in the appropriate order and place draw a sketch of the EM Spectrum below. Make sure that you copy every card as it is in front of you. This will be graded based on how many you place in the correct spots. Make sure that you label your sketch.

Answer the following questions in complete sentences where appropriate.

1. Which visible color has the highest frequency and shortest wavelength? _____

2. How are radio and gamma rays different? _____

_____

_____

3. How (specifically) are radio and gamma rays similar? _____

_____

_____

4. Why are the similarities and differences important to know in terms of studying the objects in space? _____

_____

_____

5. Give a use for each of the parts of the EM spectrum below.

Radio waves _____
Microwaves _____
Infra red rays _____
Visible rays _____
Ultra Violet rays _____
X-rays _____
Gamma Rays _____

6. Which rays are unable to penetrate the Earth's atmosphere in great quantities?

_____

7. Why are they unable to penetrate the atmosphere? _____

8. Why is that good news for the living things on the planet? _____

V. Mini Web Quest

The students will need the computer and Internet access to complete these tasks. The tasks are written in a step by step manner that the students can follow in completing their journey through the world of X-rays.

See the following worksheet for student directions.

Web sites used in the Web Quest are
http://rxte.gsfc.nasa.gov/docs/xte/outreach/epo2002.html
http://heasarc.gsfc.nasa.gov/docs/xte/learning_center/discover_0400.html
http://heasarc.gsfc.nasa.gov/docs/xte/learning_center/discover_0200.html
http://imagine.gsfc.nasa.gov/docs/science/know_l2/sun.html
http://heasarc.gsfc.nasa.gov/docs/objects/heapow/archive/solar_system/moon_pspc.html

Worksheets are on the next page.

Name _____
Date _____
Period _____

Activity V
Mini-Web Quest

Follow the following directions. Make sure that while you are on the computer you only look at the sites on this paper or relevant links from the sites listed on this paper. Answer all of the questions on your own paper. When answering the questions make sure you label which question you are answering and which part of the quest the question comes from.

A) Turn the computer on and go to http://heasarc.gsfc.nasa.gov/docs/xte/learning_center/discover_0400.html. This is a RXTE web site. Look through this page and pay close attention to the pictures. About half way through the page you see information under the heading "Watching the X-ray Sky..." Read the information and watch the animations associated with the reading.

Answer the following questions based on the long animation.

QUESTIONS:

1. The movie depicts the X-rays that are being emitted from various objects in space. Name at least four objects that emit X-rays.
2. What are some characteristics of an object that emits X-rays?
3. Why can't we see these images with our eyes?
4. Why do satellites have to be in space for our instruments to pick up the X-rays.

B) Go to the site
http://heasarc.gsfc.nasa.gov/docs/xte/learning_center/discover_0400.html
. You can do this by typing in the above address, clicking on the above address, or by clicking on the link "RXTE Learning Center Discoveries Page" from the original page. Look through the information on this page.

QUESTIONS:

1. Why do scientists use the RXTE?
2. What is the most prominent X-ray emitting object
3. What is the Crab Nebula?

C) Go to
http://heasarc.gsfc.nasa.gov/docs/xte/learning_center/discover_0200.html
Read this link and answer the following questions.

QUESTIONS:

1. What is the only sign of a black hole that scientists can observe? Why?
2. What is an accretion disk, and why is it visible in the X-ray spectrum?
3. What happened on September 15, 1999? Why was this unusual? What did scientists see before and after September 15, 1999?
4. Describe a quasar in terms of its characteristics.

D) Go to http://imagine.gsfc.nasa.gov/docs/science/know_l2/sun.html

QUESTIONS:

1. Why is the sun an excellent source of X-rays even though its temperature is only measured at 6000K?
2. Scroll down and watch the movie of the sun in quick time format.
   A) Just by watching the movie, describe what you see.
   B) What causes the flares that are being emitted from the sun?

E) Go to
http://imagine.gsfc.nasa.gov/docs/science/know_l2/crab_xray_orig.html

QUESTIONS:

1. Just by looking at this image, what can you tell about the X-ray emissions?
2. What can you tell about the temperature of this object relative to other objects?

F) Go to
http://heasarc.gsfc.nasa.gov/docs/objects/heapow/archive/solar_system/moon_pspc.html

QUESTIONS:

1. Why does it appear that the moon is emitting X-rays?
2. Why is the entire moon not emitting the same amount of X-rays?

Closure

Orally discuss the activities that the students encountered. You may want to go over questions the students have or devise questions of your own. It is the teacher's choice to devise and implement a formal assessment.